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STUDIES ON SULPHUR FRACTIONS IN SOILS OF RAJKOT DISTRICT, GUJARAT

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ABSTRACT

An investigation was carried out to studies on sulphur fractions in soils of Rajkot District (Gujarat), India. Two hundred eighty surface (0-15 cm) soil samples from 14 talukas of Rajkot district were collected and analyzed to study different forms of sulphur and their relationship with soil chemical properties. The soils of Rajkot district were alkaline in reaction and found safe limit of electrical conductivity for growing crops. Organic carbon content in study area was low to medium while, these soils were calcareous in nature. The pH of soil was negatively correlated with non-sulphate and total sulphur. The EC and organic carbon content of soil was positively correlated with all the forms of sulphur except non-sulphate sulphur in case of EC. The $CaCO_3$ content of soil had significant positive relationship with all the forms of sulphur except mono calcium phosphate extractable and adsorbed sulphur. Available S were categorized as low and medium in soils of Rajkot district.

KEYWORDS: ***Soil pH, EC, Organic Carbon, $CaCO_3$, Sulphur Fractions***

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Research Article

INTRODUCTION

At present, importance of secondary nutrients particularly sulphur (S) and micronutrient is being increasingly recognized with increase in their deficiencies in several crops leading to losses in terms of quantity and quality. Sulphur is now being recognized as the fourth major nutrient in addition to nitrogen, phosphorus and potassium. The deficiency of sulphur in soils and plants are being reported by several parts of the country and also from Gujarat state. Sulphur occurs in soils as both organic and inorganic forms. In most soils organically bound sulphur are the dominant fractions of sulphur combined with carbon and nitrogen. Organically bounds sulphur can be divided into two groups, first one carbon bonded include S of amino acids and the second is non-carbon bonded includes phenolic and choline sulphates as well as lipids. The inorganic forms of sulphur in soil consist mainly of SO-S. Sulphur adsorbed as SO_4^- ions is reduced in plants and incorporated in organic compounds, proteins are the compounds in which most of the sulphur of plant tissue is incorporated. In soil, sulphur can be broadly grouped into five forms viz; total S, organic S, non-sulphate S, available S and water soluble S. The nature and amount of various forms of S depends on variation in soil texture, pH, calcium carbonate, organic matter and other soil characteristics (Xiao et al., 2015). Balanagoudar and Satyanarayana (1990) reported that the availability of sulphur is influenced by various soil factors and hence the status of different forms of sulphur in soil varies widely with the soil type. Since no information is available regarding different sulphur fractions in soils of Rajkot district, the present study was undertaken to assess the status of different forms of sulphur and delineate the area of deficiency or sufficiency of sulphur in the reported area.

MATERIALS AND METHODS

Geographically, Rajkot district is situated at 20° 58'56" to 23° 08'13" N latitude and 72° 20' 05" to 71°40'53" E longitude in Saurashtra peninsula of Gujarat. The area has three distinct physiographic regions: Eastern hilly region, alluvial plain of Bhadar valley in the west and south west parts and Northern plains. Basalt is the dominant rock in the region but have sedimentary beds of fossiliferous and calcareous rock types in the northern plains and alluvium in Morbi and Maliya talukas. The climate is hot semi-arid with soil moisture is Ustic and soil temperature regime hyper thermic. The soils of this area are classified in orders Entisols, Inceptisols and Vertisols (Sharma et al., 1994). Rajkot district falls under three agro climatic zone as South Saurashtra (Jetpur, Dhoraji and Upleta talukas), North Saurashtra (Padadhari, Lodhika, Jasdan, Rajkot, Gondal, Wankaner, Morbi, Tankara, Jamkandorna and Kotda Sangani talukas) and North West agro climatic zone of Gujarat (Maliya-Miyana taluka). The district has 14 talukas with 856 villages. Groundnut, cotton, sesame, castor, pulses (green gram and black gram), cereals(pearl millet, sorghum & maize) are the main *kharif* crops and wheat, cumin, garlic, onion and gram are main *rabi* crops in Rajkot district. Total 280 surface soil samples (20 soil samples from each taluka) were collected from different villages and analyzed for different chemical properties *viz.*, pH, EC, organic carbon and $CaC0_3$ (Jackson, 1973). The soil samples were analysed for total sulphur (Chapman and Pratt, 1961), Organic sulphur was estimated by the procedure described by Evans and Rost (1973). Sulphate sulphur, water soluble sulphur and heat soluble sulphur were analysed as described by Williams and Steinbergs (1959). Non-sulphate-S was computed by subtracting the sum of organic –S and SO_4^- S from the total-S as given by Chesnin and Yein (1951). Simple correlations were worked out relating different S fractions with chemical properties of the experimental soils by standard statistical methods (Panse and Sukhatme, 1985).

RESULTS AND DISCUSSIONS

Chemical Properties

The results (Table 1) revealed that soils of Rajkot district were neutral to moderately alkaline in reaction (pH 7.15-8.79) with mean of 7.98 The alkaline reaction of soil was probably due to the presence of sufficient free lime content and basaltic alluvium parent material rich in alluminosilicates and alkaline earth from which these are derived. The EC of the soils ranged from 0.11-2.40 with mean values of 0.35 dS m^{-1}. The $CaCO_3$ content varied from 15-240 with mean value of 131 mg kg^{-1}. It was observed that most of the soils were calcareous to highly calcareous in nature. This might be due to hyperthermic temperature regime and deposits of lime stone rocks in which $CaCO_3$ content increased in surface soil. The organic carbon content of soils varied from 1.15-7.62 with mean value of 4.90 mg kg^{-1}. The 30 to 85 per cent soils of different talukas of Rajkot district was found low in organic carbon content. District as a whole, 51.4 and 48.6 per cent soils were found low and medium category in organic carbon content, respectively, From the value, it was clear that majority of soil samples were low to medium in range. The agro climate and agro ecological unit is very important from standpoint of soil fertility and plant growth. The content of organic carbon in soils depends on the range of precipitation within experimental area, considerable variation in precipitation was observed. The differences in the level of organic carbon in these soils were largely attributed to the pattern of rainfall in the area. Malewar et al. (2004) reported that organic carbon was also attributed to variation in decomposition rate.

The Sulphur Fractions in Soils of Rajkot District

Total Sulphur

The total sulphur content in soil ranged from 176 to 522 with mean value of 345 mg kg^{-1} (Table 2). The highest mean value of total sulphur (408 mg kg^{-1}) was recorded in Gondal taluka (alluvial plain) and the lowest (308 mg kg^{-1}) in Tankara (light soils). The considerable variation in the total sulphur content in soils might be due to varying cropping systems and parent materials (Aggarwal and Nayyar, 1998). Balangodar and Satayanarayana (1990) reported that sulphur status varies with the soil type depending upon soil pH and drainage characteristics of the soils. These observations corroborate the findings of Bhan and Tripathi (1973) and Jat and Yadav (2006).The Table 3 revealed that the total sulphur exhibited significant and positive correlation with organic carbon (0.568**) and EC (0.329**). Bhatnagar et al. (2003) reported that total S appears to be a function of soil organic matter as both are significantly and positively interrelated. Similar observations were also reported by Aggarwal and Nayyar (1998) and Trivedi *et al.* (1998). The total S was negatively correlated with CaCO3 (-0.306**) and pH (0.220*) of soil. Negative relationship between pH and total S was also reported by Sharma and Gangwar (1997). Similar relationship was also reported by Jat and Yadav (2006) and Patel et al. (2008).

ORGANIC SULPHUR

The organic sulphur content of soil varied between 28 to 481 (mean 290 mg kg^{-1} and accounted for 72.7–87.1 % (mean 84.1 %) of the total S (Table 2). The highest mean values of organic sulphur 357 mg kg^{-1} in soil were recorded in Gondal taluka (alluvial plain), while the lowest mean 274 mg kg-l in soil Tankara (light soils). Similar range and mean values for organic sulphur were also observed by Patel and Patel (2008) in South Gujarat and Jat and Yadav (2006) in Jaipur district of Rajasthan. Correlation studies (Table 4) indicated significant and positive correlation of organic-S with organic carbon (0.634**) and EC (0.176*). The positive relationship of organic-S with organic carbon suggested a simultaneous increase in the status of organic-S in soil (Sharma and Gangwar 1997). The organic sulphur was negatively related with $CaCO_3$ (-0.139*). A significant and negative correlation of organic S was found with pH, $CaCO_3$, clay and CEC. It showed significant and positive correlations with organic carbon, silt and total N (Bhatnagar et. al. (2003)

Sulphate Sulphur ($CaCl_2$ Extractable)

Sulphate sulphur ranged from 1.30 to 128.5 (mean 14.4 mg kg^{-1}) in soils (Table 2). Sulphate sulphur showed wide variation in soils of different talukas. The highest overall mean value of sulphate sulphur (45.4 mg kg^{-1}) was recorded in Upaleta (Sounth Saurashtra region) and the lowest (6.3 mg kg^{-1}) was recorded in Tankara (North Saurashtra) soil. Sulphate-S showed positive with organic carbon (0.251*) and EC (o.675**) while, negative correlation with $CaCO_3$ (-0.207*). Similar relationship was also reported by Chaudhary and Shukla (2002).

Non-Sulphate Sulphur

The data (Table 2) indicated that the nonsulphate sulphur content ranged from 3.6 to 157.1 (mean 31.2 mg kg^{-1}) in soil. The increase or decrease in non-sulphate sulphur depends on the organic sulphur and sulphate sulphur in soils. The maximum range (13.6-157.1mg kg^{-1}) was noticed in Upaleta taluka, while lower range (3.6-63.7mg kg^{-1}) was noticed in soil of Kotada Sangani taluka (Table 3). The values of non-sulphate sulphur are comparable as reported by Kumar and Singh (1999) and Jat and Yadav (2006) in different soils. Non-sulphate-S showed a significant and positive relationship with organic carbon (0.477**), while the pH (-0.365**) and $CaCO_3$ (-0.378**) of soil has significant negative relationship

with non-sulphate-S. Similar type of relationship was also reported by Sharma and Gangwar (1997).

Water Soluble Sulphur

The water soluble sulphur ranged from 1.7 to 40.9 (mean 5.7 mg kg^{-1}) in soil (Table 2). The soils of the highest overall mean value of sulphate sulphur (8.5 mg kg^{-1}) was recorded in Dhoraji taluka (Comparatively deep soils) and the lowest (3.5mg kg^{-1}) was recorded in Jasadan taluka (hilly soils) soil. The mean values of water soluble sulphur are in conformity with the findings of Patel and Patel (2008). Water soluble-S showed a significant positive correlation with organic carbon (0.225*) and EC (0.588**) but negative with $CaCO_3$ (-0,203*). Sharma and Gangwar (1997) and Singh et at. (2006) also reported similar relationship (Table 3).

$Ca(H_2PO_4)_2$ Extractable Sulphur

Mono calcium phosphate extractable sulphur content varied from 4.6 to 156 mg kg^{-1} (mean 22.4 mg kg^{-1}) in soil. $Ca(H_2PO_4)_2$ extractable sulphur showed wide variation in soils of different talukas. The highest overall mean value of sulphate sulphur (72.9 mg kg^{-1}) was recorded in Upaleta (Sounth Saurashtra region) and the lowest (12.4 mg kg^{-1}) was recorded in Jasadan taluka (hilly area) soil. Data (Table 3) indicated that the monocalcium phosphate extractable sulphur showed a significant positive correlation with pH (0.147*), EC (0.748**), $CaCO_3$ (0.218*) and organic carbon (0.333**). Relatively higher values was recorded with mono calcium phosphate extractable sulphur in comparison to heat soluble sulphur content in soil of the district.

Heat Soluble Sulphur (Available)

Heat soluble sulphur content varied from 3.6 to 141.8 mg kg^{-1} (mean 19.6 mg kg^{-1}) in soil (Table 2). Relatively higher amounts of heat soluble sulphur were recorded in Upleta, Dhoraji, Jetpur and Morbi talukas in comparison district mean value. The value of heat soluble is in conformity with the findings of Patel and Marsonia (1985). Heat soluble-S showed a significant positive correlation with organic carbon (0.335**) and EC (0.768**) but $CaCO_3$ (-0.343**) showed negative relationship (Table 3).

Delineate Area of Sulphur Deficiency and Sufficiency

Data (Figure1) revealed that the maximum per cent deficiency (50) of available sulphur was observed in soils of Tankara taluka may be due to light soils having shallow depth and that of minimum (10) in soils of Upleta and Dhoraji taluka may be due to medium black soils having higher depth. District as whole, 32.1 percent soils fall under deficient category, while 44.6 percent in medium and only 23.2 soils are in high range. Delineation of soils of different regions of the Gujarat State for available sulphur based on more than 7000 soil samples indicated that the sulphur deficiency is wide spread and it from 15 to 56 per cent with an average of 37 (Meisheri and Patel, 1996).

CONCLUSIONS

- The minimum and maximum values of various sulphur fractions were recorded in soils of Tankara and Upleta, respectively.
- Values of all fractions of sulphur were increased with increase in soil depth.
- District as whole 32.1 per cent soils fall under deficient category, while 44.6 per cent in medium and only 23.2 soils are in high range.

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APPENDIXES

Table 1: Basic Properties and Nutrient Status of Soils of Rajkot District

Properties	Range	Mean	Category (%)		
			Low	Medium	High
pH	7.15-8.79	7.98	Alkaline		
EC dS m^{-1}	0.11-2.40	0.35	Non saline		
$CaCO_3$ mg kg^{-1}	15-240	131	Calcareous		
Organic Carbon mg kg^{-1}	1.15-7.62	4.90	51.4	48.6	0

Table 2: Range and Mean of Sulphur Fractions in Soils of Different Taluka of Rajkot District (Mg Kg^{-1})

Taluka	Water Sol. Sul.	Heat sol. Sulphur	$CaCl_2$ Sulphate Sulphur	$Ca(H_2PO_4)_2$ Extract Sulphur	Absorbed Sulphur	Non sul Sulphur	Organic Sulphur	Total Sulphur
Kotda Sangani	2.1-9.9 (4.4)	4.2-47.8 (14.8)	2.0-41.8 (10.4)	4.6-52.6 (16.3)	2.6-12.9 (5.9)	3.6-63.7 (30.9)	207 -382 (300)	267-422 (342)
Paddhari	1.9-6.4 (3.5)	5.7-25.4 (11.4)	4.0-21.9 (9.1)	6.3-28.0 (12.6)	1.2-11.1 (3.6)	4.2-91.7 (25.6)	170-383 (284)	210-404 (319)
Maliya-Miyana	1.7-7.4 (2.6)	5.4-37.4 (12.2)	6.4-21.6 (10.4)	8.9-41.1 (15.7)	1.2-19.5 (5.3)	6.5-128.2 (30.1)	158-420 (299)	176-456 (340)
Jasdan	2.1-4.6 (3.0)	5.7-20.4 (11.5)	1.8-14.5 (8.6)	6.3-22.5 (12.9)	1.9-14.2 (4.4)	7.3-71.5 (26.9)	159-375 (282)	186-396 (318)
Lodhika	1.9-13.3 (3.9)	5.6-30.4 (13.2)	4.9-30.6 (14.5)	8.2-35.1 (20.2)	2.4-15.4 (5.7)	8.4-104.4 (28.1)	148-335 (280)	209-319 (322)
Morbi	2.1-30.1 (5.7)	5.9-79.7 (20.1)	2.3-50.2 (12.8)	9.9-72.4 (22.1)	3.1-22.2 (9.3)	4.6-73.1 (31.5)	200-390 (277.0)	211-432 (322)
Rajkot	1.9-11.6 (3.8)	5.3-34.3 (13.7)	2.2-27.4 (9.8)	5.8-37.7 (15.3)	2.2-16.4 (5.5)	9.2-99.5 (38.4)	185-355 (285)	233-383 (333)
Wankaner	2.0-14.7 (5.9)	6.4-43.1 (19.5)	1.3-39.7 (12.5)	6.5-43.2 (21.1)	2.5-21.4 (8.6)	6.81-77.9 (31.4)	208-361 (285)	244-409 (329)
Tankara	2.3-14.5 (2.5)	3.6-27.1 (10.9)	4.7-16.5 (6.3)	8.5-20.6 (14.7)	1.5-11.6 (8.4)	5.3-107.1 (27.7)	128-315 (274)	183.4-368 (308)
Gondal	2.7-11.0 (6.3)	5.1-41.2 (17.7)	3.1-31.1 (12.4)	5.6-45.4 (19.5)	1.1-14.2 (7.1)	4.7-88.9 (37.9)	229-481 (357)	247-552 (408)
Jetpur	2.7-13.9 (6.6)	6.4-113.6 (20.8)	3.1-99.6 (14.2)	7.0-124.8 (22.9)	5.0-25.2 (8.6)	9.3-84.2 (29.9)	218-443 (327)	244-529 (371)
Jam Kandorna	1.8-13.7 (6.3)	4.2-78.7 (18.1)	2.4-65.0 (11.8)	4.6-86.6 (20.0)	2.2-21.6 (8.1)	10.6-57.5 (27.9)	171-338 (279.9)	225-408 (319.6)
Upleta	3.4-40.9 (16.4)	8.3-141.9 (66.2)	2.8-128.5 (45.4)	9.0-56.0 (72.9)	4.8-46.2 (27.6)	13.6-157.1 (39.8)	217-409 (315)	304 -514 (400)
Dhoraji	4.9-19.7 (8.5)	7.3-84.0 (24.5)	2.8-64.3 (23.0)	8.0-92.4 (26.9)	5.2-28.1 (3.9)	10.6-93.5 (37.0)	226-428 (334)	266 -511 (394)
District as whole	1.7-40.9 (5.7)	3.6-141.8 (19.6)	1.3-128.5 (14.4)	4.6-156.0 (22.4)	1.1-46.2 (8.0)	3.6-157.1 (31.2)	128-481 (290)	176-552 (345)

Table 3: Correlation Coefficient between Chemical Properties and Sulphur Fractions

Parameter	Wat. Sol.S	Heat sol. S	$CaCl_2$-Sulp	$Ca(H_2PO_4)_2$	Absorbed S	Non sul S	Organic S	Total S
pH	0.063	0.063	0.045	0.147*	0.043	-0.375**	0.087	-0.220*
EC dS m^{-1}	0.588**	0.768**	0.675**	0.748**	0.781**	-0.109	0.176*	0.329*
$CaCO_3$	-0.203*	-0.343*	-0.207*	0.218*	0.242*	-0.378**	-0.139*	-0.306
Org.C.	0.225*	0.235*	0.251*	0.333*	0.372**	-0.477**	0.634**	0.568**

* Significant at 5% level, ** Significant at 1% level

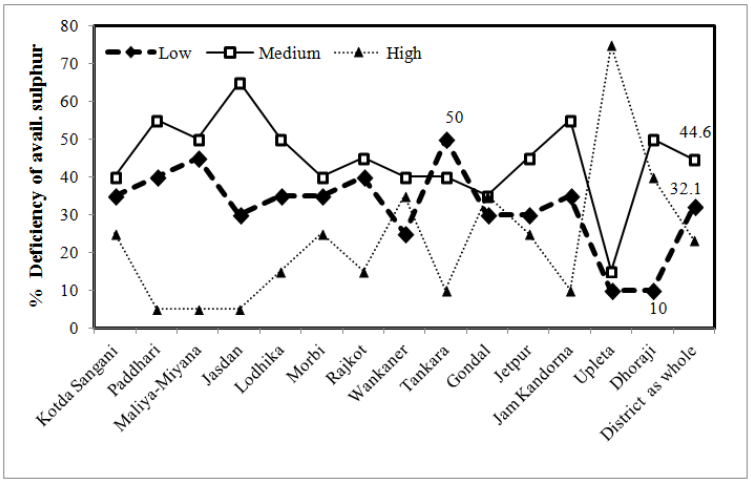

Figure 1: Percent Deficiency of Heat Soluble Sulphur in Soils of Rajkot District